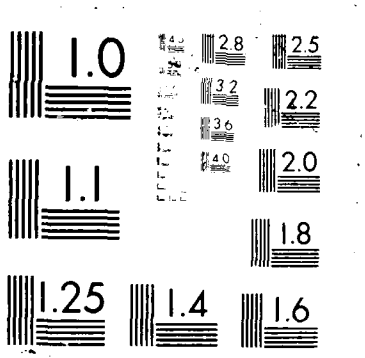
AD-A193 016 COGNITIVE AND INSTRUCTIONAL FACTORS IN THE ACQUISITION 1/1
AND MAINTENANCE OF SKILL(U) PITTSBURGH UNIV PA LEARNING
RESEARCH AND DEVELOPMENT CENTER.. A LESGOLD ET AL.
UNCLASSIFIED 26 JAN 88 N00014-79-C-0215 F/G 5/8 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release; distribution unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): UPITT/LRDC/ONR	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Learning Research and Development Cntr., U.of Pgh. / 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: Personnel and Training Office of Naval Research (Code 1142PT)
6c. ADDRESS (City, State, and ZIP Code): 3939 O'Hara Street, Pittsburgh, PA 15260	7b. ADDRESS (City, State, and ZIP Code): 800 North Quincy Street, Arlington, VA 22217-5000
8a. NAME OF FUNDING / SPONSORING ORGANIZATION / 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N00014-79-C-0215
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
61153N	RR04206	RR04206-0-	NR157-430

11. TITLE (Include Security Classification): Cognitive and Instructional Factors in the Acquisition and Maintenance of Skill: Final Report to the Office of Naval Research UNCLASSIFIED

12. PERSONAL AUTHOR(S): Alan Lesgold, James Greeno, Robert Glaser, James Pellegrino, William Chase and Michelene Chi

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM 1979 TO 1985	1988, January 26	5

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	
05	09		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of the contract was to study the psychological characteristics and instructional factors of skill acquisition in jobs requiring high levels of expertise. One of the goals of the work was to examine the acquisition of competence in skills that require hundreds or even thousands of hours of instruction and practice. This work was carried out by a collection of several separate research projects which were combined into a single grant for the convenience of the government. Each of these separate projects has reported at length about its work, in archival publications, extended status reports to ONR, technical reports. This final report is a compilation of information about the many outcomes that have been separately published.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Susan M. Chipman	22b. TELEPHONE (Include Area Code): (202) 696-4318 / 22c. OFFICE SYMBOL: ONR 1142PT

DD Form 1473, JUN 86 — Previous editions are obsolete — SECURITY CLASSIFICATION OF THIS PAGE: UNCLASSIFIED

Cognitive and Instructional Factors in the Acquisition and Maintenance of Skill:

Final Report to the Office of Naval Research

on Contract No. N00014-79-C-0215, NR 157-430

This is a final report of the activity on Contract No N00014-79-C-0215, NR 157-430, which was awarded to the Learning Research and Development Center, the University of Pittsburgh, by the Personnel and Training Research Program, Psychological Sciences Division, Office of Naval Research.

The purpose of the contract was to study the psychological characteristics and instructional factors of skill acquisition in jobs requiring high levels of expertise. One of the goals of the work was to examine the acquisition of competence in skills that require hundreds or even thousands of hours of instruction and practice. This work was carried out by a collection of several separate research projects which were combined into a single grant for the convenience of the government. Each of these separate projects has reported at length about its work, in archival publications, extended status reports to ONR, and technical reports. This final report is a compilation of information about the many outcomes that have been separately published.

J. R. Anderson, J. G. Greeno, P. J. Kline, & D. M. Neves (1981). Acquisition of problem-solving skill. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

W. G. Chase & M. T. C. Chi (1981). Cognitive skill: Implications for spatial skill in large-scale environments. In J. H. Harvey, (Ed.)., *Cognition, social behavior, and the environment.* Hillside, NJ: Lawrence Erlbaum Associates.

> Derives principles of skilled performance from the literature of cognitive skills and uses a map-drawing study to explore a critical component of spatial knowledge. The study concludes that normalizing errors in large-scale environments are caused by incorrect representations at higher levels in the knowledge hierarchy. Also addresses the question of what cognitive processes underlie cognitive maps and cognitive mapping from an information-processing analysis of spatial knowledge.

M. T. C. Chi. Interactive roles of knowledge and strategies in the development of organized sorting and recall. In S. Chipman, J. Segal, & R. Glaser (Eds.) *Thinking and learning skills: Current research and open questions,* (Vol. 2). Hillsdale, NJ: Lawrence Erlbaum Associates.

> How effective is the teaching of a new cognitive strategy? The teaching of decontextualized strategies is now thought to be ineffective. This study demonstrates that children can benefit from instruction on the use of a new strategy in a domain provided that their previous knowledge of the domain is coherent and well organized. More generally, the experiments suggest a relation of interdependence between knowledge and strategies.

M. T. C. Chi, P. Feltovich, & R. Glaser (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5,* 121-52.

An investigation of problem solving skill in physics through experiments that contrast experts' problem-solving procedures with novices'. Experts and novices were found to begin problem representation with specifiably different problem categories. Their categorization depended on different knowledge. Novices' representations of the problems depended on literal features of the problem, such as the apparatus named, while experts' representations were based on the physics principles underlying the problems.

M. T. C. Chi, R. Glaser, & E. Rees (1982). Expertise in problem solving. in R. J. Sternberg (Ed.) *Human abilities: An information-processing approach.* Vol. 1, pp. 7-75. Hillsdale, NJ: Lawrence Erlbaum Associates.

A review of the state of our current understanding of human problem solving, with particular attention to the fact that effective problem solving requires well-structured, domain-specific knowledge. The need to study ill-structured problems, the kind most often encountered in the "real world," is discussed.

D. Gitomer & R. Glaser. (1987). If you don't know it, work on it: Knowledge, self-regulation, and instruction. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning, and instruction. Vol. 3: Conative and affective process analyses* (pp. 301-326). Hillsdale, NJ: Lawrence Erlbaum Associates.

R. Glaser. (1982). Instructional psychology: Past, present, and future. *American Psychologist, 37,* 292-305.

R. Glaser & J. W. Pellegrino. (1982). Improving the skills of learning. In D. K. Detterman (Ed.), *How and how much can intelligence be increased?* Norwood, NJ: Ablex.

R. Glaser. (1982). Instructional psychology: The acquistion of knowledge and skill. In R. Glaser & J. Lompscher (Eds.), *Cognitive and motivational aspects of instruction* (Vol. 7). NY: North-Holland.

R. Glaser. (1983). Cognitive variables in series completion. *Journal of Educational Psychology, 75,* 603-618.

R. Glaser. (1984). Education and thinking: The role of knowledge, *American Psychologist, 39,* 93-104.

How can the new understanding of human thinking and problem solving contribute to instructional practices? Efforts to improve the skills of reasoning and problem-solving are considered in the light of current theory and findings in cognitive science. After discussion of the interaction between the development of problem-solving and learning skills and the acquisition of structures of domain-specific knowledge, suggestions are made for developing thinking abilities in the course of acquisition of domain-specific skill.

R. Glaser & S. Goli. (1985). *Cognitive components of expertise and the transfer of training.* Brussels: NATO Learning Research Laboratory.

R. Glaser (1986). On the nature of expertise. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities: Mechanisms and performances.* Amsterdam: Elsevier North Holland.

R. Glaser. (1986). Training expert apprentices. In *Learning Research Laboratory: Proposed research issues.* AFHRL-TP-85-54.

J. Greeno, (1983a). Conceptual entities. In D. Gentner & A. L. Stevens (Eds.), *Mental models.* Hillsdale,

NJ: Lawrence Erlbaum Associates.

Explores hypotheses about ways in which representational knowledge influences problem solving. The author discusses empirical findings and theoretical analyses in support of his hypotheses about the importance of the ontology of problems (what entities are included in the representation of the problems). He indicates that the ontology of a problem may affect the solving process

- by making analogies between domains more or less difficult;
- by determining what information will be available for general reasoning procedures;
- by determining what kinds of information can be read out directly and what kinds will need to be computed;
- and by determining the entities available in an early stage for planning.

J. G. Greeno, Forms of understanding in mathematical problem solving. (1983b). In S. G. Paris, G. M. Olson, & H. W. Stevenson (Eds.). *Learning and motivation in the classroom.* Hillsdale, NJ: Lawrence Erlbaum Associates.

J. G. Greeno, M. E. Magone, & S. Chaiklin. (1979). Theory of constructions and set in problem solving. *Memory and Cognition, 7,* 445-461.

J. G. Greeno & M. S. Riley (1981). *Processes and development of understanding.* Pittsburgh: Learning Research and Development Center, University of Pittsburgh.

J. G. Greeno, M. S. Riley, & R. Gelman (1984). *Cognitive Psychology, 16,* 94-143.

This paper presents a framework for characterizing competence for cognitive tasks. It is proposed that competence has 3 main components: conceptual, procedural, and utilizational competence. Conceptual competence is considered in particular detail. The use of the framework is exemplified by a detailed examination of children's counting performance.

J. G. Greeno & H. A. Simon, (In press). Problem solving and reasoning. In R. C. Atkinson, R. Herrnstein, G. Lindzey, & R. D. Luce, (Eds.), *Stevens' handbook of experimental psychology,* (Revised edition). NY: Wiley.

A. M. Lesgold. (1984). Acquiring expertise. In J. R. Anderson & S. M. Kosslyn (Eds.), *Tutorials in learning and memory: Essays in honor of Gordon Bower.* San Francisco: W. H. Freeman.

Reviews the roles of knowledge, automatized skill, and strategy in expert performance. Gives special attention to the importance of initial problem representations in expertise and to capacity limitations that impede their use by those with intermediate levels of skill. Discusses strategy in the light of the importance of specific domain knowledge. Makes suggestions for the development of a theory of coaching that is informed by emerging psychological account of expertise.

A. M. Lesgold. (1983.) Intelligence: The ability to learn, or more? A Review of *Handbook of Human Intelligence* by Robert S. Sternberg. *Contemporary Education Review, 2,* 111-120.

A review of the *Handbook* and an essay in response to it. Concludes that it is critical to our society to discover how to teach hard-to-teach skills, including learning skills.

A. M. Lesgold. (1984.) Human skill in a computerized society: Complex skills and their acquisition. *Behavior Research Methods, Instruments, and Computers, 16,* 79-87. [Presidential address to the Society for Computers in Psychology.]

Jobs that require the least training and the least flexibility are the most likely to be lost to automation. Automation also destroys apprenticeship opportunities. Therefore, the skills that are most likely to continue

to be useful are those that require such qualities as flexibility, opportunistic learning and the interpersonal skills of leadership and collaboration. Such skills characterize human expertise, as shown, for example, in studies of radiological diagnosis. Computers can be valuable tools for the large-scale and long-term research necessary to understand human expertise in order to develop effective instruction in these difficult-to-teach skills.

A. M. Lesgold (In press). Problem solving. In R. J. Sternberg & E. E. Smith (Eds.), *The psychology of human thought*, Cambridge, UK: Cambridge University Press.

An exposition of current knowledge of problem solving: how problem solving is studied and simulated for well-structured problems; human processing limitations; representating problem solving in production systems; expertise in problem solving; the acquisition of skill in solving problems; John Anderson's learning theory applied to the acquisition of problem-solving skill; practical applications of theory; creativity in problem solving.

A. M. Lesgold, H. Rubinson, P. Feltovich, R. Glaser, D. Klopfer. (In press). Expertise in a complex skill: Diagnosing X-Ray pictures. In M. T. C. Chi, R. Glaser, & M. Farr (Eds.), *The nature of expertise.* Hillsdale, NJ: Lawrence Erlbaum Associates.

P. Nesher, J. G. Greeno, & M. S. Riley. (1982). The development of semantic categories for additon and subtraction. *Educational Studies in Mathematics, 13,* 373-394.

Interprets findings that, across several countries, performance on "change," "combine," and "compare" addition and subtraction word problems showed consistent patterns of performance. Emphasizes the development of empirical, logical, and mathematical knowledge for skilled performance.

J. W. Pellegrino & R. Glaser (1982). Analyzing aptitudes for learning: Inductive reasoning. In R. Glaser (Ed.) *Advances in instructional psychology.* Vol. 2. pp. 269-345. Hillsdale, NJ: Lawrence Erlbaum Associates.

Addresses the problem of improving aptitude for learning through instruction, by focusing on the skills necessary for learning from instruction, in particular, for induction. Describes study of successful and unsuccessful attempts to solve verbal, figural, and numerical analogies suggesting that the factors that differentiate skilled from low-skill performers include manangement of memory load, organization of an appropriate declarative knowledge base, and procedural knowledge of task constraints. The implications for testing and instruction are discussed.

M. Rabinowitz & R. Glaser. (1985). Cognitive structure and process in highly competent performance. In F. D. Horowitz & M. O'Brien (Eds.), *The gifted and the talented: A developmental perspective.* Washington, DC: American Psychological Association.

M. S. Riley (1981). *Conceptual and procedural knowledge in development.* Pittsburgh: University of Pittsburgh. Master's thesis.

M. S. Riley, J. G. Greeno & J. I. Heller. Development of children's problem-soving ability in arithmetic. In H. P. Ginsburg (Ed.), *The development of mathematical thinking.* NY: Academic Press.

Describes studies that suggest that children's development of skill in solving arithmetic word problems primarily involves an increase in the complexity of conceptual knowledge--knowledge that is required to represent the situations described in the problems. Considers general issues in the development of problem-solving skill.

Technical reports

Chaiklin, S. (May 1982). *On the nature of verbal rules and their use in problem solving.* Tech. Report APS-9.

Chaiklin, S., & Lesgold, S. (July 1984). *Prealgebra students' knowledge of algebraic tasks with arithmetic expressions.* Tech. Report UPITT/LRDC/ONR/APS-16.

Chase, W. G. (1982). *Spatial representations of taxi drivers.* Tech. Report No. KBC-6.

Chi, M. T. H., & Glaser, R. (October 1983). *Problem solving abilities.* Tech. Report UPITT/LRDC/ONR/KBC-8.

Surveys the state of understanding of human problem solving, with particular attention to the roles of

- initial problem representation
- specific knowledge of a domain
- the structure of domain knowledge
- the representation and solution processes for ill-structured, real-world problems.

Feltovich, P. J. (September 1981). *Knowledge based components of expertise in medical diagnosis.* LRDC Technical Report No. PDS-2.

Consistent differences in performance among medical diagnosticians at different levels of experience in subspecialties were found in diagnostic tasks recorded in think-aloud protocols. Recurrent sources of error (bugs) were identified for the less experienced diagnosticians.

Greeno, J. G. (August 1982). *Forms of understanding in mathematical problem solving.* Tech. Report UPITT/LRDC/ONR/APS-10.

Greeno, J. G. (August 1982). *Conceptual entities.* Tech. Report UPITT/LRDC/ONR/APS-11.

Greeno, J. G., & Simon, H. (February 1984). *Problem solving and reasoning.* Tech. Report UPITT/LRDC/ONR/APS-14.

Lesgold, A. M., Feltovich, P. J., Glaser, R. & Wang, Y. (September 1981). *The acquisition of perceptual diagnostic skill in radiology.* LRDC Technical Report No. PDS-1.

A study of diagnostic skill in radiology. Five expert radiologists (10+ years' experience past residency) and eighteen residents in radiology were given chest films to diagnose. Analysis of their think-aloud protocols suggests that experts build rich mental representations of the patients' anatomy, to invoke patterns of disease that constrain the interpretation of ambiguous features, and to seek and respond to new data.

Lesgold, A. M. (January 1983). *Acquiring expertise.* Tech. Report PDS-5.

Neches, R. (August 1982). *Simulation systems for cognitive psychology.*

END

DATE

FILMED

DTIC

JULY 88